UNIVERSITY OF MAINE

The Maine Agricultural Experiment Station

ORONO, MAINE

BULLETIN 470 MAY, 1949

Progress on Some Important Insect and Disease Problems of Irish Potato Production in Maine

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A Wild Plum Thicket in Full Flower

Green peach aphids overwinter and develop on the wild plum, transferring in the spring to potatoes where they may spread leafroll and other diseases.

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PROGRESS ON SOME IMPORTANT INSECT AND DISEASE PROBLEMS OF IRISH POTATO PRODUCTION IN MAINE

G. W. Simpson[1] and W. A. Shands[2]

SUMMARY

Potatoes have been grown in Maine for more than 200 years. During that period many problems have beset the industry but there has been a continued expansion in yields and acreages. During that period there have been many changes in varieties grown. The center of production has shifted from southern and central Maine to Aroostook County in the northeastern part of the State, an area well adapted to potatoes. Maine produces 12 to 15 per cent of all potatoes grown in the country, with 85 to 90 per cent of Maine's production coming from Aroostook. Approximately 25 per cent of the Maine crop is of certified seed quality, while the remainder is sold largely as table stock. Some 26 states look to Maine annually for at least a part of their seed potatoes.

Some of the more important problems encountered in growing potatoes in Maine include those due to fungus, bacterial, or virus diseases, and to insect pests. All of these affect the growing potato plants and the yields obtained. Some of them also affect the storage and eating qualities of the tubers. The more important fungus diseases that affect the growing plants are late blight, scab, and Rhizoctonia. The bacterial diseases include ring rot and blackleg. The most important virus diseases are latent mosaic, common or mild mosaic, rugose mosaic, spindle tuber, and leafroll. Except for latent mosaic which is one of two components causing the other two mosaics, all of these virus diseases are transmitted by insects. Recovery by infected clonal lines having any of these virus diseases is not known to occur.

The relative importance of the virus diseases in Maine has fluctuated over the years and geographically within the State. Since

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The authors acknowledge many helpful suggestions from Dr. Donald Folsom, Plant Pathologist at the Maine Station.

1937 leafroll has been the most serious of the insect-borne virus diseases. Leafroll affects potato production through reduction in yield and in quality of the tubers. The yield of plants with chronic leafroll may be reduced 50 to 100 per cent, and the tubers from newly infected plants of certain varieties may show internal discoloration known as net necrosis.

The most important insect pests of potatoes are aphids, the Colorado potato beetle, the potato flea beetle, wireworms, leafhoppers, and *Lygus* bugs. In the order of decreasing relative abundance, over a period of years, the four species of aphids that attack potatoes are the buckthorn, potato, green peach, and foxglove aphids. Their relative abundance and destructiveness varies between seasons and between localities during any season.

Damage to potato plants by feeding of the aphids on the foliage is both direct and indirect. Direct damage is caused chiefly by the wingless aphids while indirect damage is due to both winged and wingless forms. Potato plants injured by the feeding of aphids show a progressive series of symptoms as the extent of injury increases. The extent of injury is determined largely by the size and composition of the aphid population. Losses in yield are most likely to occur when large populations of aphids develop on the plants in August, and are aggravated when moisture is then deficient. The variety of potato grown has an influence on the injury sustained, some varieties being more severely injured by aphids than are other varieties. Reduced yields result from a reduction in the size of tubers.

Indirect injury is the result of virus transmission which brings about loss in quality, usually not evident until the following crop is grown. An exception to this is found in the development of net necrosis in tubers of certain varieties produced by plants newly infected with leafroll.

In Maine the four important species of aphids affecting potatoes overwinter as eggs, mostly on woody plants which serve as primary hosts. The aphids spend a major part of the year on them. The more important of the recognized primary hosts are dwarf buckthorn, wild roses, wild plum, and foxglove for the buckthorn, potato, green peach, and foxglove aphids, respectively.

Although relatively little is known about the foxglove aphid, the generalized seasonal history of the other three species of aphids is about as follows. The eggs hatch when the buds begin to swell, which is usually early in May. Some individuals of the second generation are winged. Although the spring migrant forms appear over a period of several generations, most of them mature in the third

generation. As the spring migrants mature, they move to summer or secondary hosts, which are potatoes and many species of weeds. Towards the end of the summer winged fall migrants begin to mature on the secondary hosts. These fly to the primary hosts where they immediately initiate colonies. When winged males of at least the buckthorn and green peach aphids mature on the secondary hosts they also fly to the primary hosts. There they fertilize the maturing, wingless oviparous females which deposit the eggs. There is considerable variation among the several species of aphids as to when these phenomena occur during any one season and there are also marked variations between seasons, within the same species.

Potatoes are the most biologically important secondary host of the aphids because of the large acreages involved. The potatoes are colonized by the spring migrants if the plants are up that early. If not, the aphids colonize weeds which may serve as intermediate hosts. Ordinarily aphid populations on potatoes remain small until late in July when a rapid rise begins to occur. The size of the aphid population on potatoes at its peak, and the time when the peak is attained are influenced by many factors, and it varies between seasons and between localities within any season. Ordinarily the peak is reached during the latter half of August. Much variation among varieties of potatoes is found in respect to their favorableness as hosts for the different species of aphids, the total number of aphids developing, the time when winged forms begin to mature, the number of winged forms maturing, susceptibility to feeding damage by the aphids, and susceptibility to infection by the virus diseases.

Outstanding as secondary hosts among the weeds are wild radish, wild rutabaga, hemp nettle, smartweed, and lamb's-quarters. Weeds growing in wasteland and in potato fields develop larger aphid populations but those growing in competition with close-growing crops develop winged forms soon after colonization, which forms move to and colonize potatoes or augment the infestation already present on the plants. There are considerable differences between species of weeds in respect to their favorableness as hosts for the several species of aphids. Many factors influence the aphid productiveness of the several weeds, an important one of which is age, which often depends on the time of germination with respect to the time of aphid migration.

An intensive study of aphid flight over a period of several years has resulted in a better understanding of the flight habits and characteristics for those species which infest potatoes. Some of the information has been applied successfully for precisely timing the

early harvest of commercial plantings of potatoes grown for the specific purpose of obtaining seed low in disease.

Natural agencies of aphid control include parasites, predators, and fungus diseases. The degree of aphid control from their actions varies markedly for the several species of aphids and between seasons but, ordinarily, their effectiveness does not become pronounced until fairly late in the season, after aphid populations have become large.

Especially during recent years, progress has been made in the development and use of aphicides on potatoes. Most of the emphasis has been placed upon DDT. Much progress has been made toward learning how to use it most effectively. There is some possibility that the general and continuing use of effective aphicides may minimize the spread of leafroll during years when otherwise the spread would be excessive.

A well integrated and carefully supervised program has been developed and is in use in Maine to which growers of table stock potatoes may look with confidence for seed potatoes of high quality. Based upon the results of research and grower experience, the overall program is divided into four phases, namely, work of the Seed Potato Board, the Florida Test, the Foundation Program, and the Certified Seed Program.

INTRODUCTION

Historical Sketch

Since the growing of Irish potatoes for local consumption began in Maine over 200 years ago, the industry has changed with the times but the trend has been toward expansion. Beginning about 100 years ago, production in excess of local needs was first made into potato starch. Even today starch production remains an important part of the industry because much low-grade stock can be put to some use in this manner every year and, in years of surplus, additional quantities of table stock potatoes have been converted into starch. More recently, commercial uses of potatoes in making commodities such as potato chips, dehydrated potatoes, canned potatoes, frozen French fries, and alcohol have afforded additional outlets for the potato industry. With changes in the varieties grown and with the adoption of improved cultural practices, the trend in yield has been steadily upward.

In the early period, most of the potato production was located in the southern and central parts of the State. Somewhat more than 100 years ago the production of potatoes was given considerable impetus by the establishment of numerous starch factories in the central part of the

State. Farmers had turned to potatoes as a cash crop following difficulties with wheat. The development of the starch industry extended the areas of production beyond those where shipment of potatoes as such by water was feasible.

All went well until about 1844 when late blight[3] made its appearance in the State. This disease caused almost total losses in so many instances that growers were, in case after case, forced to substitute other crops for potatoes. The starch industry in the central part of the State was driven out of existence and has never been revived.

Some 40 years elapsed before an effective control for late blight was found in Bordeaux mixture. Meanwhile, in 1876, the Colorado potato beetle appeared in the State and added to the difficulties of production. The opening of the Aroostook area, economic factors, and an almost perennial lack of adequate moisture during critical periods of growth brought about a further decline in acreage in the central portion of the State. There is a section in central Maine where production of potatoes is still significant but there potato growing is commonly combined with other types of farming. Similarly there is still some commercial production of potatoes in other earlier potato-growing areas.

With the advent of rail transportation which made markets more readily available to the northeastern part of the State there was a gradual revival of interest in growing potatoes. Impetus was also added by the coming of some new varieties, the Green Mountain, for example, and the trend was again upward. Within the last 50 years the bulk of the acreage and production has come to be centered in the Aroostook area. Therefore, as farming areas go, Aroostook is a relatively young agricultural section.[4] This relatively small, but intensively cultivated, potato area in Aroostook County lies along the Canadian border largely between 67° 45′ and 68° 45′ west longitude and 45° 30′ to 47° 30′ north latitude, with the elevation ranging roughly from 500 to 1000 feet.

THE AROOSTOOK AREA

Rail transportation was not the only factor of importance in developing the Aroostook area. Better growing conditions, soils, weather, and insects were also instrumental in effecting the shift.

Aroostook soils, peculiarly well suited for growing potatoes, were formed by weathering of glacial till. The better potato land is underlain with calcareous shale and limestone, although some areas having

[3] Common names are used throughout the paper. Anyone wishing to determine the exact organism involved should refer to a list on the last page of this bulletin.

[4] The authors are indebted to Clarence A. Day for information concerning the early history of potato production in Maine.

sandstone underneath are being cultivated successfully. About 60 per cent of the cultivated area is Caribou loam which is especially well adapted to potato production. Another 16 per cent is Washburn and Chapman loam in about equal proportions. Most of the soil types used for potatoes drain quickly in the spring and following rains during the summer, yet they withstand drought remarkably well. Much erosion has taken place where potatoes have been planted up and down the slope. Soil conservation practices have been worked out to overcome most of the difficulties from erosion. An ever increasing percentage of the growers in the area are making use of modern soil conservation practices.

Weather in Aroostook also favors the growing of potatoes. Winters are usually severe enough to prevent the survival of diseased tubers in the soil. Summers are cool and rain is usually abundant and well distributed. The growing season is relatively short and is normally terminated by frost in September. Planting sometimes can be started in late April although it is more usual to start in mid-May and finish in early June.

There are fewer serious insect pests of potatoes in the Aroostook area than elsewhere in Maine. It largely escapes the wireworm problem that is of such importance in more southerly areas. The same situation obtains regarding leafhoppers and the tarnished plant bug. The potato flea beetle is considered usually to be of less importance in Aroostook than in central Maine.

IMPORTANCE OF THE POTATO INDUSTRY IN MAINE

Potatoes are grown largely for culinary purposes and for planting, these types being referred to as table stock and seed, respectively. Approximately 12 to 15 per cent of the total potato production of the United States is grown in Maine. About 85 to 90 per cent of Maine's production comes from Aroostook.

The relative importance of potatoes to the total farm income in Maine is indicated for a period of years in Figure 1. The industry has had its ups and downs but recently the income from potatoes has bulked large in the total agricultural income of the State. Some of this has been due to increased acreage to meet wartime demands while some of it is simply due to price inflation. The figure also indicates the very important place held by the potato industry in the agricultural picture in Maine. Because most of the crop is surplus, other states consume the bulk of the production. Normally most of these potatoes are consumed in the area east of the Mississippi but peculiar market conditions have occasionally resulted in shipments as far west as Oregon

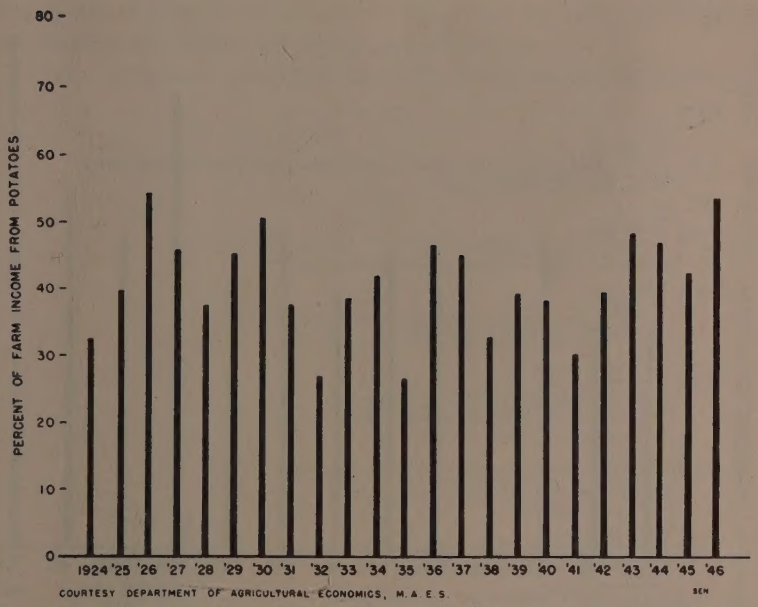

FIGURE 1. Percentage of total Maine farm income derived from potatoes 1924-1946.

and Washington. Thus consumers over a large part of the country, as well as the producers within the State, are concerned with the welfare of the table stock industry in Maine.

Shortly before World War I, the potato industry began to concern itself with possible improvements. Research was directed along many lines, one of which was the effect of virus diseases upon yield. It was found, soon after World War I, that some of these diseases were insect transmitted and that such diseases had to be controlled if losses in yield were to be prevented.

About 1914, Maine growers became interested in seed certification as a means of producing better seed for use within the State and for sale to producers in other states. From a small beginning the production of certified seed has grown to be of vast importance to the industry. It has progressed side by side with the table stock phase of the industry, helping to improve production. Occasionally it has been set back by adverse conditions in table stock fields, some of which are considered later.

The place of the certified seed industry in the State is indicated in Figure 2 which shows the trend in the acreage actually certified over a period of years. The acreage grown for certification is deter-

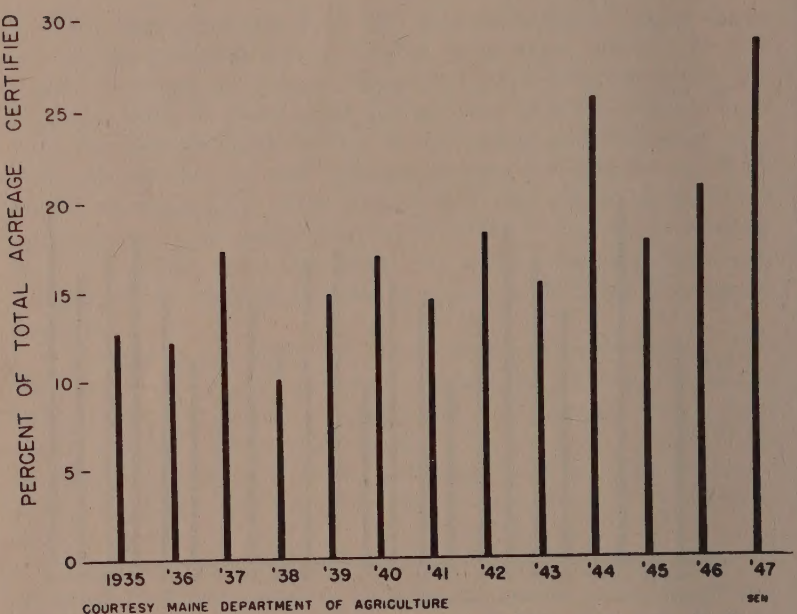

FIGURE 2. Percentage of total potato acreage in Maine passing certification 1935-1947.

mined by a combination of factors, some of which are the availability of good seed, the greater selling price expected in relation to that for table stock, and the demand for particular varieties by producers in other areas. For example, the drop in acreage in 1938 (Fig. 2) was due almost entirely to a lack of good seed following an epidemic in 1937 of a virus disease known as leafroll. Much of the increase during the war years was brought about by price relations.

The importance of Maine as a producer of certified seed in the United States is indicated in Figures 3, 4, and 5. Figure 5 presents a conservative picture, since it represents actual sales of Maine certified seed compared to the total reported production of seed for the entire country. While there have been yearly fluctuations, Maine's seed industry has been an important factor nationally, especially so for those areas actually served. Some 26 states in the eastern part of the country depend upon Maine to supply at least a part of their yearly seed requirements, and occasionally seed has been exported from Maine to South America and Europe. Since yields to be expected are dependent to such a large extent upon the quality of seed planted, it is evident that individuals over a large area have a direct or an indirect interest in

the potato industry in Maine and are influenced for better or for worse as conditions in Maine fluctuate from year to year.

During recent years about ¼ of the potato acreage in Maine has

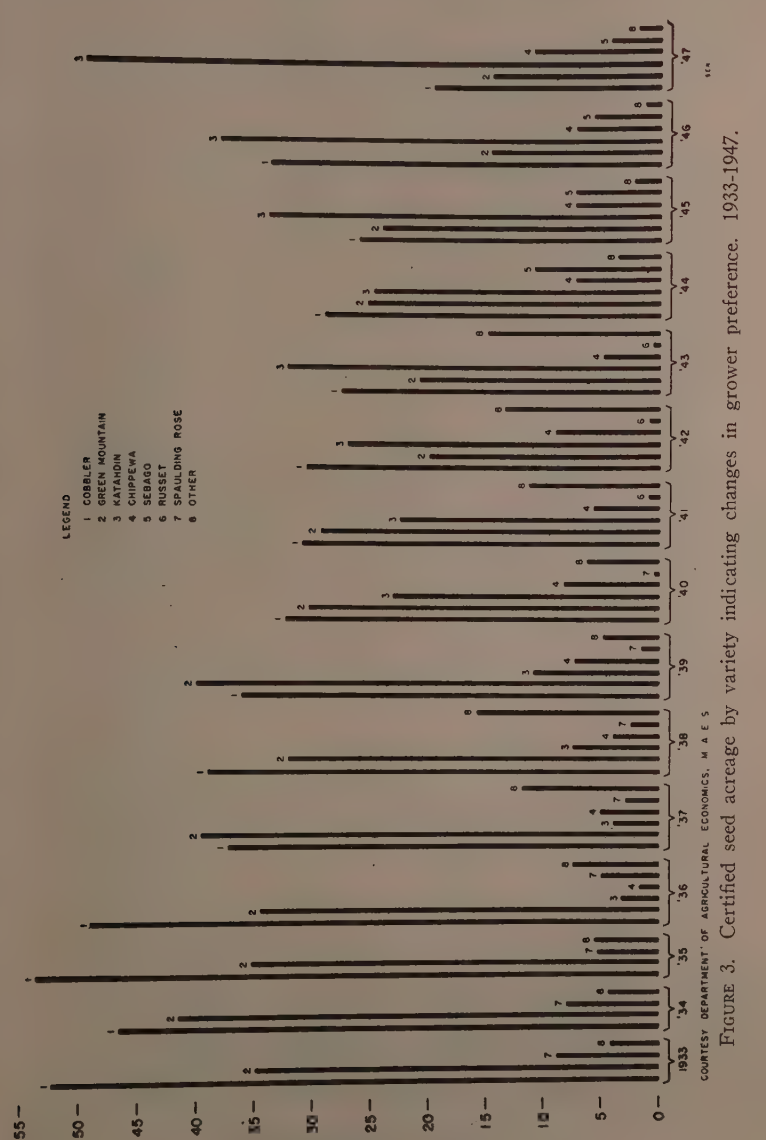

FIGURE 3. Certified seed acreage by variety indicating changes in grower preference. 1933-1947.

been devoted to the production of seed. There is no well defined seed-producing area. The personal inclination of the individual grower is usually the deciding factor and there are many growers who raise both seed and table stock. There are many disadvantages to such a program

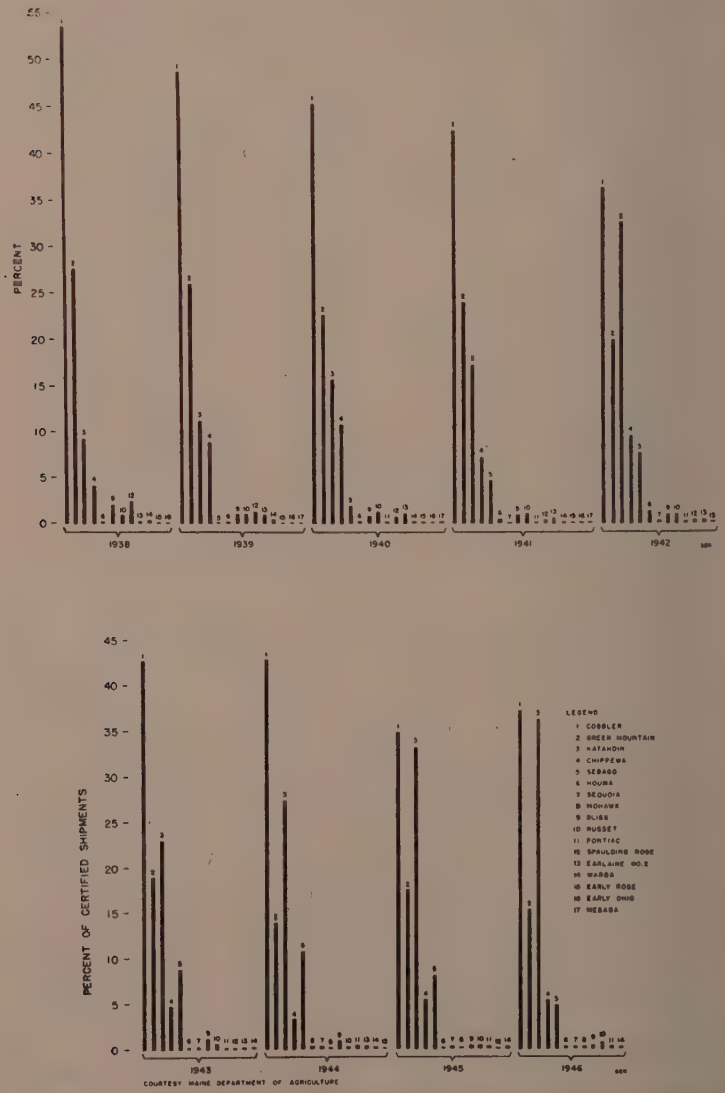

FIGURE 4. Shipments of certified seed from Maine by varieties 1938-1946.

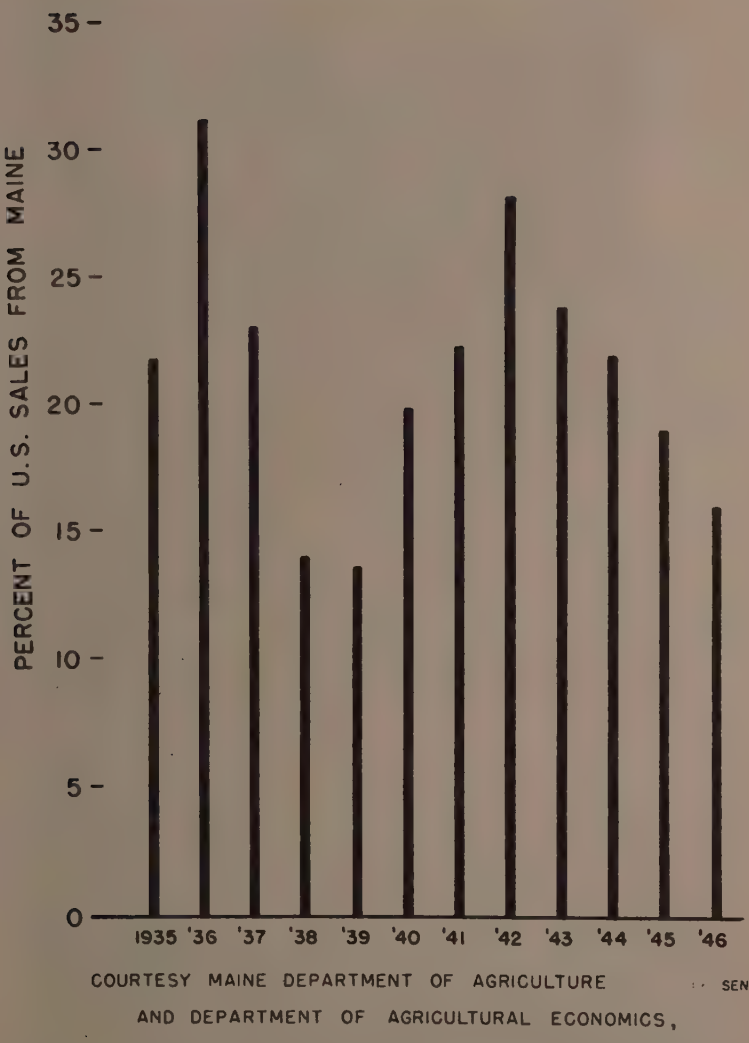

FIGURE 5. Actual sales of Maine certified seed expressed as a percentage of the total production of such seed in the U. S. 1935-1946.

because of the increased difficulties from having seed fields near table stock fields. In a few cases, seed growers have recognized the need for isolation and have been, or are developing, seed farms to the west and north of the main producing areas.

In years following low prices for table stock, much of the seed used in planting table stock fields may be inferior. In other circumstances, many table stock growers buy new seed frequently. Yearly renewal of seed stocks for certified seed and table stock planting is usually best from all points of view since it will aid in propagating only the better seed stocks.

Varieties of Potatoes Grown in Maine

A gradual shift in the potato varieties planted is apparent in Figure 6. Since the bulk of the production is table stock, the shift recorded has been influenced primarily by that segment of the industry. Many varieties planted 25 years ago have been discarded largely because early markets formerly supplied with Maine Cobblers are now supplied with potatoes grown in other states. In recent years the acreage of table stock planted with potatoes of the Green Mountain and Irish Cobbler varieties has been markedly reduced because of difficulties arising from the prevalence of leafroll. With a reduction in importance of some varieties there was concurrent introduction and an increase in importance of other newly developed varieties. For example, Fig. 6 shows that the percentage of the total acreage planted to Katahdins increased materially between 1937 and 1944 and that there was a marked decrease in Green Mountains acreage during the same period. Among the other seedling varieties recently introduced, Sebago and Chippewa have been gaining favor, although Sebago seems to be losing

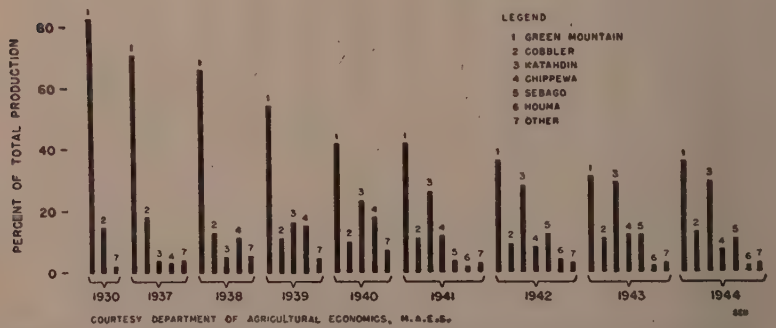

FIGURE 6. Percentage of total production in Maine represented by each variety of potato, indicating changes in grower preference. 1930-1944.

ground recently. More than 80 per cent of the acreage was planted to Katahdins and Green Mountains in 1944. The Irish Cobbler is still grown for seed. Minor acreages, primarily for seed, include varieties

such as the Bliss Triumph, Houma, Sequoia, Mesaba, Pontiac, Rural Russet, Mohawk, and, until recently, Spaulding Rose.

SOME PRODUCTION PROBLEMS IN MAINE[5]

General Production Problems

Among the many factors limiting the maximum production of potatoes and causing annual fluctuation in yield are moisture, plant diseases, and insects. The importance of most of these factors can be minimized through the adoption of better cultural, handling, and storage practices. The most important of these factors is moisture, since, with abundant or even adequate rainfall at critical periods, some of the other factors are of little importance. When rainfall is inadequate, damage from feeding by insects, for example, is aggravated. Irrigation could, in some instances, be used to supply moisture. Time of planting, in relation to seasonal development of the crop, decidedly influences yield. Although little is known about optimum conditions of storage, there is reason to believe that productivity of seed stocks is affected by the handling between harvest and planting. This probably differs from one variety to another. In general, seed held at too low a temperature right up to planting tends to be slow in germinating and the resulting plants may not set as many tubers as those growing from seed stored at a higher temperature.

Fungus Diseases

Plant diseases fall naturally into three groups depending on whether the causal agents are fungi, bacteria, or viruses. Among the fungus diseases affecting maximum production, late blight causes major losses during many years. It is the chief reason for the use of fungicides on the potato crop. Its destructiveness in unsprayed fields is well known. Losses from late blight rot of tubers in the field and in storage, although occasionally serious and widespread, are less well recognized by growers. While the severity of outbreaks of this disease seems to vary from year to year, it is an ever-present threat to the crop all along the Atlantic seaboard.

Because of its influence on stand, *Rhizoctonia* is probably of greater importance to growers than is generally realized. It also has

[5] The authors have drawn freely on experimental work, both published and unpublished, for the information presented in this paper. It has not been thought necessary to include references to all published sources of information in a paper of this nature. They do acknowledge much assistance from the literature, particularly that published by their colleagues at the University of Maine.

an effect on quality that is not often appreciated. While reasonably effective control measures are available, many growers prefer not to use them, especially if they are planting some of the newer varieties that are injured more or less seriously when the seed is treated for the control of this disease.

Scab is another fungus disease that causes considerable loss to some growers. Other fungus diseases of relatively minor importance in recent years are early blight, *Fusarium* rot, and *Verticillium* wilt.

Bacterial Diseases

The more important of the diseases of bacterial origin include a relatively new one, ring rot, and an older one, blackleg. In addition, soft-rot bacteria may cause losses in storage. The latter are often secondary invaders following late blight or ring rot.

Ring rot has been of great concern because of its highly infectious nature. Most growers are not accustomed to the precautions necessary to avoid contamination, largely because no other disease in the past has required such care. In the 15 years since the disease was first recognized in this area, growers, in general, have learned to avoid serious losses in yield. However, the strictly enforced, no-tolerance regulation for certified seed continues to inflict financial loss on seed growers who are unfortunate enough to plant infected stocks. Luckily, it has, thus far, been possible to maintain clean stocks of all varieties and, because of the rapid rate of multiplication in the potato, the industry has been able to keep abreast, if not ahead, of losses through infection of previously clean stocks.

Blackleg is of some concern in seasons favorable to its development. Since it is known that proper storage and handling of cut seed are practices which prevent the spread of blackleg, growers who handle their seed stocks carefully have relatively little trouble with the disease. Tuber unit plantings rarely have even a trace. Even the replanting of tubers harvested from blackleg hills has resulted in only trace infection the following year, providing the cut seed was handled properly.

Virus Diseases

Virus diseases need to be discussed more in detail because several of them are linked with the aphids that infest potatoes. Only one virus of major importance is not known to be aphid-transmitted. It has been designated as "X" and is commonly referred to as a latent mosaic because it is not readily apparent in the field. While its effect on yield has been suspected for many years, it was not until tests were

made with some of the recently introduced varieties of potatoes that the true picture of yield losses from latent mosaic was established. It has been shown that complete infection, especially with the stronger strains of latent mosaic, may result in yield reductions approaching 25 per cent. Unfortunately, no stocks of the older potato varieties are known to be free of latent mosaic. Hence, efforts to develop stocks free from latent mosaic must be confined to the recently introduced varieties. Experimental progress to date indicates that seedlings immune to latent mosaic can be developed from parent stocks now at hand. Because of the latent nature of the virus, all testing must be carried out using plants other than potato. Jimson weed is the test plant most used in the work in Maine. Tubers found to be free of latent mosaic are propagated as rapidly as possible and the resulting seed stocks are used to replace badly diseased stocks through the foundation program discussed later in this paper.

An interesting characteristic of the latent mosaic virus is that in a susceptible variety, when this virus is combined with one or more of the aphid-transmitted viruses, the resulting effects are more severe than either component. For example the combination of the X and Y viruses results in the disease known as rugose mosaic. Fortunately, combinations of viruses are less frequently seen today and are of much less importance than they were ten years ago, because several of the newer varieties are essentially immune to virus A, the most common aphid-transmitted mosaic virus.

Four of the aphid-transmitted virus diseases are of sufficient importance to warrant separate discussions. Thirty years ago, spindle tuber was of great importance because most seed stocks were badly diseased. This disease is one of the few that affects grade by altering the shape of the tuber and causing some malformation about the eyes. The yield of infected plants may be reduced as much as 20 per cent. While aphids and other insects are vectors of spindle tuber, it is now believed that much of the transmission is due to mechanical causes, especially cutting knives and probably picker planters. The disease spreads rather slowly in contaminated seed stocks. Spindle tuber is of little importance in table stocks because of its low incidence. The seed grower is more conscious of the disease but considers it of relatively minor importance. No genetic resistance to spindle tuber has yet been incorporated into acceptable seedlings.

Two types of potato mosaic are common, mild and rugose. Like rugose mosaic, mild mosaic results from the action of two virus components, one of which is transmitted by aphids and the other, the latent mosaic virus, is in the plant when the aphid-borne virus is introduced.

The aphid-borne components are the A-virus in the case of mild mosaic and, as indicated, the Y-virus in the instance of rugose mosaic. Excessive spread of rugose mosaic is usually associated with large populations of the green peach aphid while the potato aphid is considered to be the most important vector of mild mosaic. Neither disease affects the grade of tubers except through reduction in size. Neither combination disease assumes the importance it once had because of the large acreages now planted to the newer varieties of potatoes, most of which have but small percentages of the latent virus component and some of which are immune or highly resistant to this disease. This condition may account for the minor spread of these diseases during recent years even in the older and more susceptible varieties. However, the yield of susceptible plants infected with rugose mosaic may be reduced as much as 50 per cent, and those with mild mosaic as much as 25 per cent.

Thirty years ago, mild mosaic was a serious disease and accounted for considerable reduction in the yield of table stock. Seed growers were forced to rogue heavily to meet certification tolerances with consequent loss in production.

In recent years, mild mosaic has become of minor importance and seldom causes measurable loss in production. Seed fields are seldom disqualified because of excessive amounts of mild mosaic, although previously this had been the major cause of rejections in Green Mountains. As in the case of rugose mosaic, this shift in importance has been due largely to the rapid replacement of Green Mountains by the newer seedlings. In fact, some of these seedlings are immune to the "A" virus, having been picked for this genetic character. Mild mosaic can still be found in some stocks of Green Mountains and has been known to increase appreciably in years that are favorable for the spread of this virus. However, a persistent effort has been made to replace such stocks with others carrying little or no virus "A." This procedure, together with other measures such as careful early harvesting, has reduced the spread of virus "A" to a minimum. Unless conditions favoring the rapid spread of virus "A" return, it seems unlikely that this virus will be of more than minor importance. In addition, most new seedlings introduced will be immune, which affords further protection.

Mild mosaic has never reduced yields as severely as rugose mosaic. The success in the finding of immunity to the "A" virus was one of the first accomplishments of the National Potato Breeding Program, and in itself has amply repaid growers for all the funds so far spent for the breeding project.

The leafroll disease of potatoes is caused by the aphid-borne leaf-

roll virus, and the recovery of infected clonal lines is not known to occur. The green peach aphid is considered to be the most important vector in Maine. The disease affects potato production in two ways. The yield of individual plants affected with chronic leafroll may be reduced 50 to 100 per cent, and the tubers from newly infected plants of certain varieties may show internal discoloration known as net necrosis. Even a small percentage of tubers having net necrosis is sufficient to lower the grade, because potatoes having net necrosis are unacceptable to housewives. When the condition is widespread it thus has a depressing effect upon price.

Leafroll has had a long history. Probably it is the reason why seed certification programs have been instituted in many states. It is largely responsible for the practice of growers in the more southern areas to renew their seed periodically to prevent losses in yield from "running out."

Historically, leafroll in potatoes in Maine was associated with stocks grown in the central or southern portion of the State. There have been several outbreaks in the Aroostook area in the past 30 years and all but the last outbreak subsided promptly. During the growing season of 1937 conditions were especially favorable for the development of very large populations of the green peach aphid. It is thus not surprising that widespread infection of seed stocks took place that year. For reasons not entirely clear, conditions since then have generally favored the yearly development of green peach aphids and the infection of seed stocks has taken place almost more rapidly than new stocks, relatively free from leafroll, could be developed. For several years following the initial outbreak, good seed stocks were not available to replace contaminated stocks. Table stock growers were thus forced to plant undesirable seed and these fields, in turn, frequently served as sources of infection so that many seed fields were found, on testing, to be unsuited for further propagation. Some progress was made in those years when green peach aphids were less abundant but it was not until 1946, the first year that DDT was generally used, that aphid populations in potato fields were greatly reduced. That, coupled with the fact that green peach aphids were not numerous on untreated potatoes or on other secondary hosts, resulted in adequate quantities of good seed to replace contaminated stocks. Seed stocks of high quality were distributed from the 1946 crop to seed growers in the area east of the Mississippi with a consequent gain in food production in the whole region.

At the time of the outbreak of leafroll in 1937, nearly 90 per cent of the acreage in Maine was planted with varieties that showed

net necrosis the first year of infection with leafroll. Because of the difficulty with net necrosis, growers shifted varieties, particularly in the areas where most difficulty was encountered. After only seven seasons, the percentage of the acreage planted to susceptible varieties had been reduced to less than half of the total acreage and this trend has continued since. Almost all of this change can be attributed to the effects of the outbreak of leafroll. Some of the varieties not susceptible to net necrosis are less desirable in other respects, and the general use of DDT may revive an effort to increase the acreage planted to Green Mountains in some sections at least.

The outbreak of leafroll thus exerted considerable influence upon the varieties of potatoes grown in Maine. One of the varieties substituted for Green Mountain during this period was Katahdin. It has shown some field resistance to leafroll and is not susceptible to the net necrosis found in newly infected Green Mountains. However, repeated tests have shown that green peach aphids will multiply very rapidly on Katahdin, and that winged forms will be produced earlier in the season on Katahdin than they will be on some other varieties. This appears to be a definite disadvantage of the Katahdin variety, especially in years when conditions favor the development of large aphid populations. At present Katahdin, by a wide margin, is the leading seed variety grown in Maine. This almost automatically forces table stock growers to follow, because they are dependent on the seed growers for seed stocks. Many growers prefer to plant other varieties but often have little choice. On the other hand, a few skillful growers during the past ten years have found it highly profitable to produce good seed of varieties susceptible to leafroll, Chippewa for example.

Leafroll, or perhaps the threat of loss from the disease, has thus exerted considerable influence in determining the varieties of potatoes to be planted by growers. It has likewise determined what the consuming public would get. It would be of great interest to know what effect this choice of varieties has had on the consumption of potatoes in recent years. Katahdin does not have the cooking qualities of a good Green Mountain potato.

Insect Pests

Maine has never had to contend with some of the insect pests found in other potato-producing areas. For many years the Colorado potato beetle was the most important pest from the standpoint of reduced yields. It was never considered a serious pest, because it was readily controlled with arsenicals. When DDT replaced calcium arsenate, even more satisfactory control was possible because the DDT

kills the overwintered adults on the young potato plants, something not easily accomplished with the arsenicals. Unless resistant strains of the Colorado potato beetle evolve, this insect appears to have been relegated to a role of minor importance since, in Maine, it feeds principally on the potato plant.

Potato flea beetles have long been considered a pest of importance, especially when conditions favored an abundant summer brood. However, it was not until the advent of DDT that the real amount of damage done by flea beetles could be estimated. It is now evident that losses in yield were far higher than realized, and that the potato flea beetle must be considered one of the major pests in Maine. Its injury here is fortunately almost entirely confined to leaf feeding. DDT is very effective against both the overwintered and the summer broods of flea beetles. However, because the flea beetles can live and multiply on hosts other than potatoes, it appears likely that, in contrast to the probable future importance of the Colorado potato beetle, flea beetles may continue to be major insect pests in Maine.

In some rather restricted sections of Maine wireworms have affected the quality of the potatoes grown. Trouble from these pests appears to run in cycles and is related at least in part to the year-to-year use of the land. Some success has been reported from the use of benzene hexachloride but the effects of this chemical on the tubers are such as to discourage its use on potatoes for the present.

Minor injury to potatoes, usually local in its occurrence, is caused by blister beetles of the genus *Epicauta* and to some extent also by other leaf-feeding beetles.

A number of sucking insects are found attacking potatoes in Maine. Leafhoppers are seldom numerous although in some sections of the State, especially in the southern and central parts, they are often abundant enough to be found easily. In restricted areas there have been, on occasion, rather extensive outbreaks and probably some loss in yield has been sustained. No thorough study has ever been made in Maine of the leafhoppers found on potatoes but it is known, as the result of studies in other States, that DDT is effective against these insects.

Lygus bugs are generally present, and, while usually not abundant on potatoes, there seems reason to believe that they cause more damage than has been suspected heretofore. Several other plant bugs can be found on potatoes in certain sections of Maine in some seasons. None of these species presents particular problems to the potato grower. The general use of DDT has certainly reduced the injury from these bugs and has, at the same time, made it evident that even though insect

populations have appeared to be small they, in the aggregate, have caused losses in yield not suspected previously.

Some loss of stand occurs almost every year from attacks by the common stalk borer. Injury is normally confined to the margins of fields and has never been observed to affect much more than five per cent of the plants. Usually the injury is confined to a fraction of one per cent of the plants.

Aphids are by far the most important of the insect pests of potatoes in Maine. Their incidence varies greatly from season to season and from field to field in any given season. Over the period of years for which records are available the buckthorn aphid has been most numerous, followed by the potato aphid and the green peach aphid. There have been seasons and locations where this order has been reversed, particularly during the past ten seasons. The fourth species, the foxglove aphid, has, in general, been less abundant than the other species but usually just as widespread.

APHIDS AS PESTS OF POTATOES IN MAINE

Feeding damage by the aphids (direct injury to the potato plant) and transmission of virus diseases by the feeding aphids (indirect injury to the crop) are of importance in the production of potatoes for seed as well as for food. Reduction in yield of tubers is the normal result from both types of injury. Injury caused by direct feeding is confined to the plants on which the aphids are found, while indirect injury is evident chiefly in subsequent crops that grow as progeny. It is usually not possible to separate, with certainty, the immediate reduction in yield of potatoes caused by aphid feeding from that caused by other insects, especially the potato flea beetle.

Direct Damage

Direct injury to the potato plant is caused chiefly by wingless aphids. The proportion of winged aphids increases somewhat as the intensity of damage to the plant increases, and also just before the start of the fall migrations of the aphids, but wingless aphids predominate throughout practically the entire life of infested plants. While direct injury from feeding by winged aphids is of some moment, these forms are chiefly of importance in colonizing uninfested plants and in augmenting the population of wingless aphids on infested plants.

The typical symptoms of severe aphid damage to potato plants are familiar to many, but the progressive development of symptoms on plants less heavily populated by aphids has been less readily recog-

nized. The seasonal development of such symptoms has been followed by repeated observation of small plots of potatoes subjected to differing seasonal levels of aphid population. One of the early signs of injury is the beginning of an accumulation of honeydew on the upper surfaces of some of the leaves. This is followed by an increasingly unthrifty appearance of the plants. Soon, especially if rainfall is deficient, the lower leaves of the plants begin to yellow and drop. The yellowing and dropping of leaves continues up the plant until often only a few of the upper leaves remain alive. Eventually the plants die prematurely. Small patches of dead plants, usually appearing as circular spots over the field, gradually enlarge as the aphids move from dying plants to adjacent ones that are in better condition. Eventually, the areas of dead plants converge and the whole field is ready for premature harvest.

The large amount of damage caused by the removal of fluids from the plants by large aphid populations, even though soil moisture is adequate, is indicated by the similarity in response of plants subjected to drouth conditions. The removal of the aphid population from a severely injured plant results in a response similar to the revival, by ample soil moisture, of a drouth-affected plant. Potato plants tend to recover somewhat when adequate moisture follows an extended drouth or when the plants are suddenly relieved of large populations of aphids, provided the initial damage was not too severe. New growth develops and the plants may continue to grow until frost. It follows, of course, that soil moisture could be an important factor influencing the severity of damage that results from feeding by aphids.

The amount of injury inflicted by aphids is in large measure dependent upon the composition and size of the aphid population on the potato plants. Although data are not available, it may be assumed that the quantity of plant fluids ingested by the several species of aphids is roughly proportional to the relative sizes of the several species. Based on size differences, it would appear, when equal numbers of aphids are involved, that the most injury to potato plants will result from feeding by the large potato and foxglove aphids, somewhat less from the green peach aphid, and the least from the small buckthorn aphid.

Despite its small size, over a period of years, the buckthorn aphid, because of its predominance, probably causes more direct injury to the potato crop, in Maine, than any other species of aphid. Further, large populations usually develop on individual potato plants owing to the more sedentary habit of this species. The other species tend to wander more from one plant to another and are less often found in large colonies. When abundant, the green peach aphid soon inflicts

considerable damage to potatoes, especially if associated with the buckthorn aphid, as is usually the case.

There have been years when serious injury to potatoes has been caused by the potato aphid, but this aphid is not often present in large numbers over a large area. It seldom causes, in Maine, over an extensive area, the severe foliage injury usually associated, in more southerly regions, with damage by this aphid. Perhaps the fact that it attacks potatoes earlier in the development of potato plants farther south has a bearing on this difference. In Maine, populations of the potato aphid have never become large after the potato plants have completed flowering. When large populations have been found, they have been large before the plants have flowered. The foxglove aphid seldom has been abundant enough to inflict much damage to the growing plants.

Numerous experiments have shown that potato yields increase rapidly after mid-August. Since it is usually after that time that aphid populations on potatoes are largest, it is not surprising that the relationship between the size of aphid population and plant condition at that time exerts such an important influence upon the ultimate yield of tubers. Weather conditions during that period, particularly as they affect soil moisture, have an important bearing upon the final effect of aphid injury upon yield.

Studies have shown that the variety of potato affects, in two ways, the severity of aphid injury that will result. Some varieties are more favorable than others as hosts for one species of aphid, while other varieties may be better hosts for other species of aphids. (Some varieties are more susceptible to aphid feeding than others.) Recent experiments at Aroostook Farm have shown that the yield of Katahdin potatoes may be markedly reduced when the plants are infested early in the season by even small numbers of aphids. Other studies showed that when field-growing plants of the Katahdin and Green Mountain varieties were intermixed, presumably with the same chances for colonization by aphids, larger populations of the green peach aphid developed on the Katahdins than on the Green Mountains, while larger populations of the buckthorn aphid developed on the Green Mountains.

Recent studies in Maine have shown that the reduction in yield from aphid damage is brought about by a reduction in the size and in the number of tubers grading U.S. No. 1. In Green Mountains the reduction is due about equally to each effect. During a three-year period, when differing levels of aphid abundance were maintained in one field on small plot plantings of potatoes, it was found that, in

general, the amount of reduction in yield was correlated positively with the level of aphid abundance on the growing plants.

Indirect Damage

With the exception of leafroll, the transmission of virus diseases from diseased to healthy potato plants is of immediate concern chiefly to the grower of seed potatoes. From a broader standpoint, however, growers of potatoes for both seed and table stock are profoundly affected because once a plant is infected with a virus disease all of its succeeding progeny will be infected. Therefore, if a seed grower is unsuccessful in controlling the spread of virus diseases, the table stock grower will be unable to obtain suitable seed. Large acreages of potatoes carrying an excess of virus diseases result not only in reduced yield but they serve also as important reservoirs for further spread to fields of seed potatoes growing nearby.

Both kinds of growers have immediate concern with the effect of the leafroll virus upon tubers produced by newly infected plants. For example, tubers from newly infected plants of the Green Mountain and Irish Cobbler varieties may develop net necrosis, which affects their sale for seed or food. The seed grower, in the instance of leafroll, has no such concern with varieties that do not develop net necrosis in the tubers, because he can dispose of his seed on the table stock market if he finds, through a test planting in Florida, that his crop is unsuitable for seed.

Both winged and wingless aphids serve as vectors of several of the virus diseases that affect potatoes. Because of their mobility, the winged aphids are important as vectors both within and between fields, while this action by wingless aphids is principally within fields. The most serious outbreaks of virus diseases in northeastern Maine have always been associated with large numbers of winged aphids.

The aphids, as previously mentioned, are not of equal importance as vectors of the virus diseases that affect potatoes. For example, the green peach aphid has been found to be of greatest importance in the transmission of leafroll. There is reason to believe that the foxglove aphid may be next in importance, although this is by no means established beyond doubt. The potato and buckthorn aphids are of considerably less importance as vectors of leafroll. The green peach aphid is, by far, the most important vector of those virus diseases of most concern in the area.

There are two periods during each season when transmission of virus diseases occurs most generally, *viz.*, early in the season soon after the plants come up, and again during the latter part of the season,

principally during August and early in September. The greatest amount of spread occurs during the latter period because of the larger numbers of both wingless and winged aphids then on the plants, together with the extensive flights of the winged aphids that occur almost daily at that time. The early season spread, although less extensive, should not be minimized, because an increase in the abundance of disease reservoirs at that time will enhance the possibility of increased spread later when vectors are more abundant.

Early season spread of virus diseases is effected principally by the winged aphids. These are the spring migrants and the early-season dispersal forms from intermediate hosts. Late-season spread is caused by wingless and by winged aphids breeding on potatoes and by winged aphids that move from other secondary hosts to potatoes. The importance of fall migrants as vectors is not known. It has been found that the roguing out of diseased plants very early in the season is an effective means of reducing subsequent spread of disease by the aphids and that early harvesting of the crop can eliminate much of the spread that would otherwise occur late in the season.

BIOLOGY OF THE APHIDS

In Maine, all four of the species of aphids infesting potatoes overwinter out of doors in the egg stage. Because of the rather short growing season, most of the year is spent on the primary hosts and a large part of that time is passed in the egg stage. Primary hosts for each species are fairly specific. As is usual with migrating aphids, a much wider host range is found among secondary hosts during the growing season. Actually the potato is the most biologically important secondary host because of the area devoted to this crop. Large populations develop in favorable seasons on this crop.

PRIMARY HOSTS AND SEASONAL HISTORY OF THE APHIDS

The buckthorn aphid. Dwarf buckthorn is the only recognized primary host of importance for the buckthorn aphid in Maine. Other species of *Rhamnus,* when present, can serve in this capacity. Dwarf buckthorn is quite widespread throughout Maine and is often found at no great distance from potato fields. It is found, chiefly, in rather swampy locations which means that it is not often disturbed by cultivation. It is found in more upland areas but only rarely so.

The eggs of the buckthorn aphid normally hatch about the time the buds of the dwarf buckthorn begin to swell in the spring. Actual calendar dates will vary considerably from season to season depending

on snow coverage and average temperatures. Stem mothers usually mature about the third week in May and migrants may be found by the time potatoes begin to break ground shortly after mid-June. Caged colonies of the aphid have continued to produce winged migrants through mid-July, although normally, the aphid is not found on buckthorn that late in the summer. Limited observations indicate that a few winged migrants are produceed in the second generation but that most of the migrants mature in the third generation or later. The fall migration begins about August 10 in most seasons, indicating that the primary host is infested for about eleven months out of each twelve-month period. The fall migration continues over a period of at least a month, depending on seasonal conditions. Males mature on potatoes by the time that the first fall migrants appear, or very shortly thereafter, thus assuring fertilization of the oviparous females that develop on buckthorn. It is usual to find eggs on dwarf buckthorn during the first week in September. Egg deposition continues, in favorable seasons, into October.

The buckthorn aphid seems to be very well adjusted to conditions in Maine. It is an annual pest of potatoes and, while subject to some fluctuation in abundance from year to year, has been more consistent as a pest of potatoes than the other three species of aphids. In a survey of aphid eggs covering several years, far more eggs of the buckthorn aphid have been found per unit of infested branches of dwarf buckthorn than those of any of the other aphids on their respective primary hosts.

The green peach aphid. Wild plum, the only recognized primary host of the green peach aphid in Maine, is widespread in the cultivated portions of the State. Fall migrants of the green peach aphid with large colonies are frequently found on the closely related bird cherries and chokecherries. However, repeated observations over a series of years have failed to disclose spring colonies of the green peach aphid on either kind of cherry.

Wild plum is not known to occur in the unmolested forested areas. Wild plum is believed to have been largely introduced here and to have escaped subsequently. It is known to have been used extensively as a rootstock by nurserymen about 65 years ago. The distribution of the plant today fits in well with the theory that it got its start in most locations from plantings of home orchards. Later, when many of the tops of the cultivated plums died, the rootstocks were able to survive and to grow into the thickets that are so characteristic today.

The eggs of the green peach aphid hatch at the time the buds of the wild plum begin to swell. This takes place at different times depend-

ing on the season. When the eggs hatch early there appears to be more likelihood of a heavy infestation developing on the plum than when hatching is late. When the plums remain dormant late in the spring because of deep snow and frost in the ground, the aphid is less likely to become a serious pest of potatoes later. This is probably directly related, in part, to the number of generations that can develop during the season.

A relatively few overwintering eggs can develop into rather extensive infestations on wild plum. This is at least partly the result of the habits of the stem mothers. These forms seem to develop fairly high up on the plums but to descend when mature to low growing whips or undergrowing seedlings. Here the stem mothers start numerous colonies. By the time the third generation is mature, rather large numbers of winged aphids may be present on the plums. The winged forms normally migrate to secondary hosts soon after maturation although caged colonies have been maintained on plum throughout the growing season, even beyond the time of the return migration in the fall.

Stem mothers usually mature as the plums come into flower. Some individuals of the second generation are winged, but the bulk of the spring migrants are individuals of the third generation. The peak of maturation of the spring migrants is usually reached about 30 days after the wild plums come to full flower.

If weather conditions are favorable for migration, it is usual to find many secondary hosts infested shortly after the peak of maturation of the winged forms has been reached. On the other hand, it has been observed that adverse weather conditions at this period may completely disrupt migration, and secondary hosts may be but sparsely populated even though rather large populations had been present on the primary hosts.

Fall migrations of the green peach aphid have started with considerable regularity during the last few days of August. If populations on secondary hosts are not reduced by entomogenous fungi or other agencies of control, the fall migration may continue well into September or even later. Observations over a period of several years have shown that males of this species are rare until quite late in the season and that they are far fewer both in numbers and in proportion to the females than the males of the buckthorn aphid.

The fall forms on wild plum develop slowly. Newly deposited eggs have not been observed on the plum before early October and deposition may continue much later, especially if weather conditions are favorable. In fact, breeding on plum sometimes is not terminated by the complete defoliation of the trees.

Eggs of the green peach aphid have not been abundant on wild plum at any time in recent years—at least, they could not be shown to be abundant by the method of sampling employed. A precise determination of the abundance of eggs of the green peach aphid is complicated by the fact that several other species of aphids lay their eggs on wild plum. Since no way has been found to distinguish between the eggs of the several species of aphids, it has been necessary to form judgments on the basis of surveys made while aphid colonies are still found on plum foliage. These surveys have indicated that usually where any aphid eggs are found, some are green peach aphid eggs.

While the green peach aphid is quite able to maintain itself in Maine, several aspects of its biology indicate that it is near the northern limit of its natural occurrence. It is distinctly less well adapted to its environmental conditions here than the buckthorn aphid, and probably for this reason is not an annual pest of potatoes. Past experience indicates that the green peach aphid may be important in recurring cycles, but that, in northeastern Maine, seasonal conditions must be favorable if large populations are to develop. Farther south in the State, there is more likelihood of finding the insect every year.

The potato aphid. Several species of wild rose, of which the Scotch rose is the most important, serve as primary hosts for the potato aphid. Since wild roses flourish in Maine it is not surprising to find many rose patches about the countryside. Many of these patches have developed close to old, abandoned home sites and in other such places not now being cared for. These patches are at no great distance from potato fields, which makes easy the migration of the potato aphid in both directions.

Eggs of the potato aphid begin to hatch rather early in May. Seasonal differences have been observed. The peak of spring migration usually comes in mid-June and is made up largely of individuals of the third generation. Under artificial conditions the potato aphid may continue to breed on rose throughout the summer. Normally roses are deserted by the end of June.

The fall migration of the potato aphid is not as well defined as that of the buckthorn or of the green peach aphid. It usually commences in August and continues for some time. Eggs are deposited before all of the leaves of the roses fall. The abundance of eggs has varied from year to year and from one rose patch to another. The situation here, also, is obscured by the fact that other aphids, especially a species of *Capitophorus*, likewise use the rose as a primary host.

The potato aphid is not often found in large numbers on its primary host but roses are very abundant. Consequently, it is usually

found on potatoes where, in some seasons, it becomes a major pest. Outbreaks of the potato aphid appear to be associated with cool seasons, whereas in the case of the green peach aphid major outbreaks have occurred in seasons when temperatures have been above normal.

Serious outbreaks of the potato aphid seem to occur when populations become fairly large by or before the time potatoes flower.

The foxglove aphid. Very little information is available concerning the biology of this aphid in Maine. Sources of infestation have not been located and it is not known just how the yearly infestation of potato fields takes place. Some of the available evidence indicates the possibility of long distance flights. The only recognized primary host, the foxglove, is not known to be abundant in northeastern Maine. Certainly it is not sufficiently widespread and abundant enough to account for the infestation found during recent years on potatoes in Maine. If other primary hosts exist, they have not yet been recognized. Few, if any, fall migrants have been found, perhaps indicating that they are not necessary for the survival of this insect.

Secondary Hosts

There are a number of secondary hosts more or less common to all of the four species of aphids. Observations over a period of years have shown that there are variations in the relative importance of particular hosts both within and between seasons. Differences have also been found in the relative importance of particular plants in the production of winged and wingless aphids.

Potatoes. Potatoes constitute the most biologically important of all the secondary hosts in the area. This in many ways is a fortunate situation. Because potatoes are cultivated, it is possible to apply insecticides for reducing aphid populations on the crop. The use of insecticides is discussed later in this paper.

As was indicated earlier, potatoes are sometimes above ground when spring migrations of the aphids occur. When they are not yet up the aphids must colonize other secondary hosts, which may serve as intermediate hosts.

When potatoes are colonized directly by spring migrants, it is often difficult to detect the beginning of the infestation, and growers are likely to feel that there is no need to begin control measures. However, repeated experience at Aroostook Farm has shown how difficult it is to obtain thorough coverage by aphicides on the rapidly expanding foliage so characteristic of the potato plant during its early season development. This is an important reason for beginning the application of aphicides early.

Winged migrants are sometimes sufficiently numerous to be detected without difficulty in routine aphid counts made on potatoes in late June. The winged forms do not appear to survive for a long time, but within two or three weeks (mid-July) colonies may be found throughout an infested field. Within a week or ten days from this time (about July 20 to 25) populations increase rapidly in size. It is at this time that the stage is set for later developments. If conditions are favorable for rapid aphid development, the populations may continue to increase into September or until the plants are killed earlier by the aphids. Ordinarily, however, the peak of population is reached during the latter half of August.

If the beginning of control measures is delayed beyond the period when aphid populations are set to develop, it has been found far more difficult to effect their satisfactory control. Experimental results have shown that under such circumstances potato yields will not equal those obtained from plants protected from early in the season.

Along with the rapid increase in size of the aphid populations on potatoes there is a gradual increase in the numbers of winged aphids that mature. There may or may not be a corresponding increase in the ratio of winged to wingless forms.

The winged forms produced first are the summer dispersal forms. Within a relatively short time in the case of the buckthorn aphid—later for the green peach and potato aphids—the winged dispersal forms are joined by the fall migrants. Winged males, at least those of the buckthorn and green peach aphids, begin still later to mature on the secondary hosts. The fall migrants return to their respective primary hosts where they immediately initiate colonies.

The winged migrants and their progeny on primary hosts are joined still later, in the case of the green peach and buckthorn aphids, by winged males. Throughout this whole period winged dispersal forms continue to develop on the secondary hosts and they continue to infest and reinfest secondary hosts during that period. Records for several years have shown that winged forms may survive on the secondary hosts even beyond killing frost, since trapping records show catches of the winged aphids as late as early in November.

The development of these winged forms depends on the development of populations of wingless aphids. If parasites and predators become numerous, or if fungi attack the developing aphids, there is much less likelihood of large populations developing. There appears to be some relationship between the time of initial colonization of potatoes by the aphids, the stage of maturity of the potato plant at that time,

and the size of the aphid population that ultimately develops on the plants.

Varietal differences in potatoes in regard to favorableness as aphid hosts are of interest. Previously mentioned were results of tests which showed that larger populations of one species of aphid may develop on one variety of potato than on another. Other experiments showed that there were similar varietal characteristics in regard to the rapidity, after initial colonization, with which winged aphids will mature and in regard to the total number of winged aphids produced. For example, winged green peach aphids develop sooner and in larger numbers on potatoes of the Katahdin variety than they do on many other varieties.

In a study to determine whether such characteristics have a genetic basis it was found that varieties could be grouped to represent graded differences in degree of favorableness as aphid hosts from almost resistant to very favorable. A few seedlings have been found on which large populations of green peach aphids do not develop under conditions similar to those favoring the development of excessive populations on Katahdins.

There seems good reason to believe that recent outbreaks of the green peach aphid were made more severe by the planting of large acreages of Katahdins following the shift from Green Mountain caused by net necrosis in the latter variety. This shift is not, of course, the sole reason for the increased abundance and importance of aphids during recent years but it is probably a contributing factor of some significance. The general, and effective, use of aphicides may change the picture again because by their use the numbers of winged aphids on potatoes can be kept at a relatively low level and far fewer winged forms will develop to fly from field to field.

The important aphid-transmitted virus diseases of potatoes are believed to be restricted to this host in Aroostook. This means that aphids transmit disease only as they have access to diseased potato plants. No evidence has thus far been secured in Maine to indicate otherwise. Aphids developing on diseased plants are thus the most likely vectors. This is the chief reason why the roguing or removing of diseased plants in a field of potatoes is one effective means of controlling these diseases. In practice, the virus-vector complex, in recent years at least, has been largely leafroll and the green peach aphid. A more detailed consideration of the relationship found here may be of interest.

There appear to be two sources of infection. One of these, a minor one, is the overwintering of diseased tubers and their growth the following year as volunteers. Leafroll, for example, is carried over winter

in tubers produced by newly infected plants or in tubers from diseased plants not rogued in the field. Since leafroll plants frequently produce rather small tubers these tend to be missed in harvesting. If snow cover comes before the ground freezes, such tubers are protected from freezing and may develop the following year in grain or clover fields where they may remain unnoticed. Or, they may germinate somewhat later than the planted crop if that field is replanted to potatoes. If they come up late in the potato rows, they are difficult to detect but are nonetheless effective sources of infection. For these reasons, it is essential, particularly in an area where both seed and table stock potatoes are grown, that the best possible seed be used so as to reduce infection centers to a minimum.

The second, and much more important, source of leafroll infection is the planting of diseased seed pieces. This is sometimes done of necessity because better seed is not available. But sometimes it is the result of ignorance of the risk involved.

The Florida Test was developed partly to eliminate this risk. Samples of seed planted in Florida, chemically treated soon after harvest in Maine, produce plants by midwinter which indicate the prevalence of certain virus diseases in the lots of seed from which the samples came. The test thus serves to locate the best seed sources for use in Maine the following season.

Diseased potato plants cannot always be rogued from field plantings before they have served as sources of infection for aphids. Carefully trained individuals can usually detect diseased plants rather early in the season, especially in tuber unit plantings. Such plants can often be eliminated before they become infested with aphids. However, repeated experience has shown that a few diseased plants are likely to become infested by aphids before roguing is possible. It is not unusual to find, later in the season, that plants adjacent to rouged units have become infected with leafroll. This is probably one reason why the removal of the last trace of disease from a planting of potatoes is practically impossible. The probable source of these early infections is to be found in the earliest of the spring migrants of the green peach aphid that reach potatoes directly. If, by chance, they alight on a diseased plant and feed, they acquire the virus and can, after a short incubation period, disseminate leafroll for the remainder of their active lives. One characteristic of the green peach aphid is its restless nature and its tendency to move to other plants after depositing a nymph.

Since some little time is required for a recently infected potato plant to show disease symptoms, it is not possible to recognize and rogue these plants before they may serve to infect later dispersal forms

of the aphid. Then, too, any wingless aphids that develop on an infected plant may wander to adjacent plants and so infect an ever-widening circle of healthy plants.

Later in the season, when winged aphids become more numerous, an additional factor is involved. This is the tendency of the winged aphids to move from field to field, usually aided by the wind. It is believed that this situation brings about widespread transmission of leafroll and that sources of infection are largely diseased table stock fields. During recent years at least, severe outbreaks of leafroll have been associated with excessive numbers of winged green peach aphids. This point of view is supported by the known effectiveness of the proper timing of early harvest operations in potatoes so as to follow closely the maturation of large numbers of winged green peach aphids. Excessive spread of leafroll usually takes place late in the season (mid-August on) although the period has varied somewhat depending on the seasonal development of the green peach aphid population.

Experimental evidence indicates that, eventually, the potato plant reaches a condition, physiologically, beyond which it can no longer become infected or, if so, only with difficulty. This point may be reached because of a lack of moisture, because of direct aphid damage or simply because the plant is reaching the end of its growing period. The whole problem may be related in some way to a slowing of the translocation of food materials. It is a situation that needs to be investigated more fully.

It seems likely that an increasing percentage of winged aphids may become vectors of leafroll as the season advances but it also seems evident that a point is finally reached where they are no longer effective vectors because of the decreasing susceptibility of the potato plants to infection late in the season.

There are well recognized differences between varieties of potatoes with respect to susceptibility to infection with leafroll. Green Mountains and, especially, Chippewas are likely to become infected to a much greater extent than Katahdin or Irish Cobbler under apparently identical conditions. Other varieties show varying degrees of susceptibility to infection that usually fall between these two extremes. There are differences that appear to be associated with the time infection takes place in relation to the time of normal maturity of a variety. For example, Cobbler may become infected to a much greater extent in a year when winged green peach aphids are numerous early in August than will be the case when the peak of flight comes early in September. This again suggests a physiological basis for differences.

The relationship between Katahdins and the green peach aphid

seems of particular interest in this connection. As has been indicated, Katahdin does not become infected readily with leafroll under field conditions. But, as has been mentioned, green peach aphids find it an excellent host, and winged forms tend to develop earlier and in greater numbers on it than on many other varieties. It appears, then, that Katahdin may, in years when green peach aphids develop rapidly, produce large numbers of winged aphids. These, in turn, may fly to fields planted to more susceptible varieties, acquire leafroll from diseased plants, and bring about excessive spread of this disease.

It is believed that this is essentially what happened in the early years of the current leafroll outbreak. At that time Katahdin was less extensively planted but was found throughout the area. As other varieties became contaminated, Katahdin, being relatively resistant to leafroll, rapidly replaced other varieties, particularly Green Mountain. If DDT reduces excessive populations of winged green peach aphids, as it seems to be doing, this should change the picture and make Katahdin less of an indirect menace to the more susceptible varieties.

Weeds. Among the many species of weeds which serve as secondary hosts of the aphids, wild radish and wild rutabaga are important as hosts for four species of aphids, especially for the green peach aphid. In many seasons, these weeds are colonized by winged migrants and so serve as intermediate hosts, carrying the aphids along until potatoes become available. Later in the season, large populations may develop, especially on weeds growing in wasteland, or in other locations where competition is not too keen. The size of the aphid population that eventually develops on these weeds depends to some extent on the way the weeds develop. If the plants are not crowded and can produce large leaves, large aphid populations are more likely to develop on the weeds.

Because of the cultural practices in the area, there is a succession of these weeds throughout the growing season. Winged aphids transfer from the early germinating plants to potatoes and to weeds that develop as a result of later cultivations. In August, there may be a general movement to and from a number of the secondary hosts.

A study of the relative importance of wild radish and wild rutabaga over a period of years has shown that they are of considerable importance as hosts for two species of aphids and of some importance as hosts of the other two species of aphids. Their relative importance as hosts has varied from season to season.

The peak size of the aphid population on the weeds, and the total number of aphids produced, depend to a considerable extent upon the time when the weeds germinate. In general, the weeds germinating

after the times of the second and third hilling operations in potatoes, in late June and early in July, are likely to be most productive of the aphids, particularly the green peach aphid. Whether the numbers of aphids produced on a weed is the most important criterion of its importance as a host, is open to debate, since large populations on later-germinating weeds are, after all, dependent on the winged forms that developed in small numbers on earlier-germinating weeds. Furthermore the small numbers of winged aphids maturing on the early weeds are the ones which may often initiate and certainly augment the aphid populations on potatoes.

Three other species of weeds of importance as hosts are hemp nettle, smartweed, and lamb's-quarters. These have usually been infested by the potato and buckthorn aphids but, in some seasons, by fairly large numbers of the other two species of aphids as well. From the standpoint of the potato crop, however, over a period of time these weeds have been considered as being somewhat less important than the two previously mentioned weeds.

When weeds serve as intermediate hosts, because they are up during the spring migration of the aphids, it is from them that the aphids, in augmented numbers, fly to potatoes and start infestations that may develop to serious proportions later. The time of this transfer—designated as a dispersal, in contrast with the earlier migration—is of much importance to potato growers because it is then that control measures in potatoes must be started if they are to be of maximum effectiveness.

There is difficulty in determining the movement of aphids from potatoes to weeds. It occurs mostly in August when there is considerable movement of winged forms. The importance of this movement has not been accurately assessed. It is of interest, however, that, in two seasons after the advent of DDT, weeds were not populated to the usual extent. This may have been a seasonal factor or it could be that the movement of aphids from potatoes to weeds may be more important than hitherto suspected in determining the number of aphids that develop on late-germinating weeds.

Because of repeated cultivation, a succession of weeds is available to aphids in potato fields and in headlands. By the time of the last cultivation of potatoes in early July, the early germinated weeds in environments other than potato fields have usually passed their peaks of importance as aphid hosts, and any winged aphids that may have developed there are ready to disperse to other hosts. This is especially true of weeds in grain fields where the weeds soon suffer from competition with the grain.

Weeds germinating in potato fields after the final cultivation are the only ones likely to develop to any size and they are likely to remain undisturbed except where hand pulling is practiced, and this is not normally done until the weeds reach an advanced flowering stage. These weeds tend to grow rather luxuriantly and to produce large leaf areas. This is, in part, due to the abundance of fertilizer available in potato fields. There is thus ample opportunity for several generations of aphids to develop on such weeds. The common practice of pulling the weeds and dropping them in the potato row merely serves to induce any aphids present on the weeds to disperse to nearby potato plants. If they are not pulled the aphids also will move from the weeds to potatoes.

It has been observed over a period of years, that when large numbers of winged aphids develop in any given season, they do so in part because weeds are heavily populated. In other words, weeds, as well as potatoes, contribute to the total population of winged aphids.

The seasons when these large populations develop have been somewhat warmer and dryer than the long-time average for the area. While it is likely that many factors influence wing development, it is usually associated, for instance, with crowding on the host plant, wilting of the plant from lack of moisture, and the maturing of the host. In other words, it appears to be a factor associated with the nutrition of the aphids.

Maturation of the host is of particular interest in connection with weeds, because when weeds germinate at successive periods, they tend also to mature in like manner. Many early-germinating weeds begin to mature about the time when potatoes reach the peak of their growth. If the weeds have been infested, they are likely to be the source of numerous winged aphids which disperse to nearby potatoes, thus adding to any infestation already present on the potatoes. A considerable part of the abrupt rise in aphid populations on potatoes, from mid-August on, can be accounted for by the influx of winged forms from weeds.

The weed sources of winged aphids shift somewhat as the season progresses. The earliest germinating weeds are normally found in wasteland that is not disturbed in the spring. These weeds are usually infested by the earliest migrants and will account for two or three aphid generations before they become less acceptable as hosts. Another source of early-season dispersal forms of the aphids is found in the weeds growing in fields of oats and, to some extent, in clover and peas. These weeds tend to become spindly and drop their lower leaves as the competing crop plants grow. It is usually found that aphid in-

festations tend to be self-eliminating in such environments, usually, in large part, through the development of winged dispersal forms. The action of predators also frequently plays an important part in the process. Colonies in such environments are not likely, in any event, to be especially large.

Attempts to control aphids on the various secondary hosts fall into two categories. Aphids may be controlled on potatoes by the use of appropriate insecticides. Those on weeds may be controlled through the destruction of the weed hosts. Unfortunately, few growers are yet aware of the relation between weeds and the aphids that attack potatoes. This results in rather careless weed control with most of the emphasis on those weeds that compete with potatoes in cultivated areas. In recent years, more effort has been given to weed control during the period when the land is in oats. Selective weed killers have been of much value in this connection.

More recently, a few progressive growers have developed the use of selective weed killers just before potatoes break through the ground. These growers find that the application of selective herbicides not only eliminates a great deal of hand work later in the season but their use also inhibits a later crop of weeds because stirring the soil by cultivation is unnecessary following effective use of weed killers. Potentially this practice should have a beneficial effect from the standpoint of aphid control as well, since it tends to destroy weeds that could later produce large populations of aphids. There seems to be reason to believe that the use of herbicides may go further toward eliminating weeds than the cultivating and hoeing now being done.

Many growers do not realize that to eliminate weeds one requirement is to prevent them from forming seed. All too often weeds are simply pulled and dropped in the row. If the plants pulled have seeds anywhere near maturity there is usually enough food stored in the plant to complete the process. Here again the chemical weed killers are superior, if only because they are used to best advantage when the weeds are still small.

APHID FLIGHT

Because of the rather direct relation between winged aphids, particularly green peach aphids, and the spread of several potato virus diseases, a study of the flight habits of the aphids has been carried on for several years. Several types of traps have been employed in this study, of which the most useful has been a wind-vane type. Traps have been operated at several different locations, usually from the time

when spring migrants are expected to mature until flight ends late in the fall.

The data from trap catches have successfully indicated both the spring and fall migrations of the aphids, usually in their early stages before sufficient numbers of aphids were on various host plants to indicate that such movements were in progress. The records obtained have been useful in indicating the period of flight, its intensity, and its composition as to the relative abundance of the several species of aphids.

The results obtained from the trapping studies indicate that there is considerable variation from season to season in aphid flight in most respects. Early and sustained flights having high percentages of green peach aphids have been associated with considerable spread of disease, particularly leafroll, as measured through the Florida Test. The more normal situation, involving flights late in August, or in September, and consisting largely of other species, has usually resulted in little or no spread of leafroll.

From a practical standpoint, the trap records have been used with reasonable success to forecast the need for, and the timing of, early harvesting operations in seed plots. Commercial producers of Chippewa seed have also used the information to time the application of top killing sprays in order to secure seed of a quality that would survive the Florida Test.

Following the use of DDT, there has been a marked reduction, especially during the latter half of the season, in the numbers of flying aphids. Whether the falling off in the numbers of winged forms has been due directly or indirectly to DDT, or to natural factors, remains to be determined.

In connection with the flight studies, an attempt has been made to determine something of the habits of winged aphids with respect to the height at which they fly, recognizing that this is determined, to some extent, at least, by the wind. During the course of the study, traps were operated at levels up to 30 feet above the surface of the soil. It was found that there were appreciable numbers of aphids moving at the highest level—in fact about as many as were found to be moving at the five-foot level. The largest numbers were normally found at about 20 feet. There were some differences between species. A larger percentage of the small buckthorn aphid tended to fly at a lower level (10 feet) than either the green peach (15 feet to 20 feet) or the potato aphid (20 feet).

The number of aphids caught in the traps indicates that there may be enormous numbers of aphids moving about during the latter part of the season. It is a continual source of wonder that any potato plants

remain healthy, following a season when winged aphids have been so numerous. However, some exploratory studies have indicated that only a relatively small percentage of the winged forms carry virus and, as has been indicated earlier, there appear to be physiological conditions in the plants that affect transmission of virus diseases to the tubers.

Recent observations have indicated that there may be well defined varietal differences in potatoes that affect transmission of virus diseases by winged or wingless forms. No definite information on this point has, as yet, been obtained.

There is also reason to think that resistance to leafroll, for example, may be associated with the numbers of infective aphids that feed on a given plant, or that plants may even be affected by the feeding of aphids in such a way that the penetration of the virus to the tubers is prevented.

CONTROL OF THE APHIDS

Natural Control

Natural agencies of aphid control are fairly abundant in Aroostook and they effect a degree of control that varies considerably from year to year. They include parasites, predators, and fungi. As is often the case, the abundance and effectiveness of these forms usually lag behind an infestation, and serve chiefly to limit its rise rather than prevent it. In isolated instances, these agents of control have been observed to be quite effective in reducing aphid populations on several species of secondary hosts. Observations in recent seasons have shown that the predators and parasites are active in plots of potatoes treated with DDT and that the percentage of parasitized specimens appears to be increased in such plots perhaps because of the lower populations present in treated plots. There has been no evidence, thus far, to indicate that the use of DDT has been harmful to the parasites of the aphids.

There are a number of predaceous forms that are known to be present in Aroostook. The most effective of these are several species of ladybird beetles. Larvae of a chrysopid are often present but are never abundant. Syrphid fly larvae are often very effective, especially in August. They are often as prevalent as the larvae of ladybird beetles.

Incidental observations over a period of years have shown that the buckthorn aphid is rarely parasitized. The same situation seems to be true of the foxglove aphid, although its relatively small numbers may make this more apparent than real. The green peach aphid is parasitized both in the spring on its primary host and throughout the summer on secondary hosts. In some situations the per cent of para-

sitized specimens has risen to rather high figures late in the season and has resulted in noticeable reduction in populations. On the whole, the potato aphid is more freely parasitized than the other three species of aphids combined.

By far the most effective of the agents of natural control are several species of fungi. When conditions are suitable for the dissemination of spores and the infection of aphids, the aphid population may be decimated almost over night. While the action of fungi is most spectacular on secondary hosts, it may also reduce fall colonies of the aphids on their primary hosts. At least three species of fungi have been recognized in Maine. Two of these are about equally effective while the third has not been observed so widely. But few details, concerning the life history of these forms, have been worked out.

Aphids killed by one or another of these fungi are sometimes found early in the season. There is often a gradual increase in the incidence of the disease with the final outbreak occurring, if at all, toward the end of August or early in September. To what extent its effectiveness depends on large aphid populations is not known.

Aphicides

Because aphid populations were low, no efforts toward the development of aphicides were made between 1921 and 1938. In the latter year, a study of possible control measures was begun, with the emphasis being placed on control of leafroll through reduction of the aphid population. In 1940, more intensive investigations were begun, with the emphasis on increased yields through aphid control. Later work has emphasized both criteria.

The early work centered around the use of nicotine sulfate, which has many disadvantages from the standpoint of use by the potato grower. Later, rotenone was shown to be cheaper and more effective than nicotine, chiefly because of its greater residual toxic qualities. It was soon seen, however, that the available machinery was not giving adequate coverage for insect control. A number of different types of machinery were tried and some improvements were made, especially in the application of dusts. The use of rotenone was gaining favor with growers about the time that supplies were cut off early in World War II. By that time, it was quite evident that yields were being adversely affected by the aphid populations that were developing almost every year.

A small supply of DDT was made available for test purposes in 1944. It proved so successful that most of the subsequent work with aphicides has been devoted to the development of its use. The material

used in 1944 was a wettable powder. The following year several different forms of DDT were tested and considerable information on dosage was obtained. It was shown that aerosols, emulsible concentrates, or wettable powders containing DDT were suitable for use on potatoes. No DDT was found in tubers from the 1946 crop thus removing one controversial question from the many being asked by growers. The widespread acceptance of DDT emulsions by growers resulted in great savings to the industry and has probably lessened the threat of harmful accumulations of DDT in the soil.

It was necessary to obtain information upon the compatibility of DDT with fungicides and with dust diluents since it is ordinarily applied in conjunction with fungicides, and because several different fungicides and several different dust diluents are used by potato growers. In common with reports from other areas, it was found that DDT could not be used with copper-lime dusts except where such dusts could be mixed immediately before use. It was found, also, that the use of DDT with Bordeaux was feasible when spraying. However, somewhat better yields were obtained when other fungicides were used with DDT.

Trials were made to compare the relative effectiveness of dusts and sprays. In most instances, the dusts were more satisfactory than sprays from the standpoints of aphid control and of increased yield of tubers, probably because of the somewhat better plant coverage they provide.

From experiments on the proper timing of applications, it was found that about one third of the increased tuber yield was due to early season applications of DDT when aphid populations were small, This was an unexpected finding, and one not entirely understood, because aphid populations are relatively low during July. Reduction of foliage injury from feeding by overwintered adults of the potato flea beetle may have constituted a part of the benefit from early season application of DDT.

Considerable effort has been expended to determine the effect of DDT on leafroll spread. Until 1948 there was no evidence that it would control spread but there was some indication that it would do much to reduce excessive spread by keeping winged aphids to a lower level of abundance over the area as a whole than would otherwise obtain. In 1948 a spray containing DDT applied to Green Mountain potatoes materially decreased the spread of leafroll in one exepriment. In this experiment the spray gave a high degree of control of the wingless aphids and there were very few flying aphids, which developed relatively late in the season.

Some of the newer insecticides have been tried in a small way. Of

these, benzene hexachloride has been found dangerous to use because it may impart an unpleasant flavor to the tubers. Others, such as parathion and toxaphene, need to be tested further before their places can be determined.

Recent advances in the field of insecticides bid fair to lessen, or perhaps even prevent, future losses due to excessive aphid populations on potatoes.

There is no indication that even the effective use of aphicides on all acreages of potatoes will reduce the annual potential aphid hazard to the crop. The only way to eliminate the problem on potatoes is to eradicate the overwintering hosts of the aphids. The removal of secondary weed hosts should also do much to minimize the possibility of dangerous infestation levels of the aphids developing on potatoes.

PROGRESS IN MINIMIZING THE APHID-DISEASE PROBLEMS

Importance of Good Seed

The experience of many years has indicated the wisdom of using seed low in disease for the most successful production of seed and table stock potatoes. Within certain limits, there is less incentive for the table stock grower than for the seed grower to plant potatoes low in disease, unless he wishes to grow Green Mountains, since moderate amounts of disease do not adversely influence yield. The seed grower has every reason to plant the best possible seed, not only to save himself extra costs in roguing but also to hold the best possible competitive position when offering his stocks for sale. Progressive growers in areas that purchase seed from Maine have found it highly desirable to be certain that the disease content is low in the seed stocks they buy. This means a demand for pretesting which has been met by Maine through the Florida Test, which is now giving advance information on the disease content of nearly one third of all the seed certified in the State. Growers who rely on this test can be reasonably well assured of getting the best seed for their money. The test has been highly successful in locating the best seed stocks in the State, and it often helps Maine growers to retain such stocks for further increase within the State before the seed is offered to table stock producers. This is extremely helpful to the whole industry, especially following a period when virus diseases have spread excessively.

Table stock producers in other areas in the East have gradually learned that they can obtain the best returns by paying attention to seed sources and making certain that the seed they use is reasonably free from disease. The practice also tends to increase the total food supply by assuring maximum yields in so far as they are influenced by virus diseases.

METHODS EMPLOYED TO PRODUCE GOOD SEED

The practices followed from year to year in the production of seed potatoes of high quality in Maine are a combination of research findings with the practical experience of the individual grower. Since the practices followed have at least an indirect influence on growers who use Maine seed elsewhere, it may be worth while to discuss the gradual development of present procedures and to describe these procedures in some detail.

Late blight and blackleg were among the first potato diseases to be studied by the Maine Station. The former is still considered a major problem. The Colorado potato beetle was also given consideration from the time it first appeared in the area. Consideration was given to virus diseases before 1914, but it was not until the early twenties that these diseases were separated and their true nature recognized. As information concerning the spread of these diseases became available, various means of reducing spread were developed. Of great importance was the institution of the tuber-unit seed plot which greatly facilitated the roguing of diseased plants. A tuber-unit plot is one in which all seed pieces cut from each tuber are planted in consecutive hills in the row. For some time, such plots were not planted by growers until after the main crop had been planted, probably because there was, at the time, little information concerning the effect of time of planting and concerning the seasonal life histories of the aphids found on potatoes in the area. Seed plots were found to be much more effective when planted early, since diseased plants were then rogued or removed before aphids became abundant and, usually, before much transmission of virus diseases occurred, and since the plants had become more nearly mature when aphid migration occurred in late summer.

A later development, based on earlier research, was the practice of pulling or killing the tops of the potato plants shortly after winged aphids began to appear in large numbers. This practice of early harvesting has been very successful in maintaining seed stocks in unfavorable seasons. Its value varies with the different varieties of potatoes, and to be most effective, it must be early enough. Its chief disadvantages lie in the extra work required and in the loss in yield, especially when aphid conditions indicate the need for starting operations early in August.

Work on entomological aspects of the aphid-disease complex in potatoes was begun soon after the relation of aphids to the transmission of virus diseases in potatoes had been established. This work has been greatly expanded and should be continued for some time to come, since many problems remain to be investigated. It is very apparent that

problems of this nature require the closest cooperation between entomologists and plant pathologists.

The Maine State Seed Potato Board

Largely because of the asexual nature of reproduction in potatoes, it is necessary to exercise special care in selecting stocks for propagation. While growers can and do learn to handle the more obvious diseases, there is little that the individual can do about latent mosaic, the most widespread of all of the virus diseases in Maine. The need for selecting, for propagation, superior stocks that are free from latent mosaic and ring rot, has been met in part through the formation of a State Seed Potato Board. Seed developed by the State Seed Board is first indexed in the greenhouse by the Agricultural Experiment Station, using Jimson weed and pepper as test plants to detect the presence of latent mosaic virus.

Individual tubers believed to be free of latent mosaic, other virus diseases, and ring rot are propagated by the Seed Board for at least two years on an isolated farm. Because of the ease of spread of the latent mosaic, it seems necessary to repeat the indexing each year for eliminating newly acquired infections and to start a new lot of seed of each variety on its way to foundation seed growers. Tubers for the second indexing are always taken from the progeny of those indexed the previous year because there is less likelihood of spread in such lots.

The testing of individual tubers is a time consuming process and is necessarily limited to relatively small numbers of tubers. At the present time the Experiment Station is indexing about 15,000 tubers per year for the State Seed Board. This usually results in enough seed to plant between three and four acres each year. The increase from this acreage is normally early harvested to prevent, in so far as possible, contamination from leafroll or the aphid-borne mosaics. It normally provides between three and four hundred barrels of seed for the second year, several dozen barrels of which must be retained for reindexing and further propagation. This leaves the Seed Board perhaps three hundred barrels for planting increase plots, or enough to plant somewhat less than thirty acres in the second year.

The second year's increase is normally divided between the Seed Board and the Foundation seed growers since the amount available is in excess of that required by the Board for the third year. In any event, the entire amount produced by the Seed Board during the third year is made available to foundation seed growers.

It often happens that the foundation seed growers do not need new seed every year, in which case excess stocks of the Seed Board are made

available to certified seed growers with the understanding that the increase will be offered first to table stock growers in Maine if they desire to purchase it for their operations.

THE FOUNDATION SEED PROGRAM

Seed sold to the foundation seed growers by the Seed Board is normally entered in the latter's Foundation Seed Program. The Seed Board contracts with the foundation seed grower to do the roguing of the seed plot for him and, in general, supervises the growing of the crop. This supervision includes advice on when to early harvest, if that operation becomes necessary in view of the aphid situation. It also includes taking from the field, at or before harvest, a sample for testing during the winter in Florida. The seed plot is usually large enough to provide the foundation seed grower with the seed he will need for his entire acreage the following year. The grower may elect to renew his seed each year through purchase from the Seed Board or he may maintain his own seed stock through the practice of early harvesting.

The following year the foundation seed grower, knowing through the Florida Test the disease percentage of his seed stock, is in a position to increase his seed stocks with the expectation of providing seed for the certified seed grower who does not wish to provide his own seed, possibly because he is not equipped to do so or for other reasons, economic or temperamental.

Five years are thus required to increase the originally-indexed seed to an amount suitable for propagation by the certified seed industry—three years in the hands of the Seed Board and two in the Foundation Program. During that time there is an increase of about 10,000 times in bulk. Each year the crop will have been carefully inspected for disease and every precaution taken to prevent contamination. After a final testing in Florida during the winter, the seed is ready to pass into the hands of a certified seed grower who will increase it once more.

THE FLORIDA TEST

The pretesting, in Florida, of tuber samples from seed stocks produced on 12 to 15 thousand acres in Maine has been of considerable help to the industry, especially when leafroll spread was extensive the preceding year.

The tuber samples, usually taken on the basis of a tuber from each barrel at harvest, are collected and transported to Presque Isle where they are treated with ethylene chlorhydrin to break dormancy before being shipped by rail to southern Florida. Normally each of about 1,500 samples consists of 820 tubers representing not more than 20 acres of

potatoes. Small acreages may be represented by somewhat smaller samples.

Planting of these samples in Florida is done in November or December depending on the season. Observation of the resulting plants is made to determine if they have virus diseases. The readings thus obtained are returned to growers in late January or early February. Experience over a period of more than ten years has shown that the results of the test are sufficiently accurate for all practical purposes.

THE CERTIFIED SEED PROGRAM

If a certified seed grower is successful in securing foundation seed with a low Florida reading (less than 0.5 per cent disease, for example) he may allow the crop to mature without bothering to rogue out diseased plants, for he will be well within the present certification tolerance. If he does not acquire foundation seed, he may find it possible, by roguing, to remove enough diseased plants to pass the two field inspections but he will find it more expensive and he will have a smaller yield in the end.

Many certified seed growers find it desirable to send samples from their seed fields to Florida for testing. In fact, samples from this source now account for more than 90 per cent of the total acreage being tested in Florida. The information that the certified seed grower obtains from the test will serve as a basis for determining whether he can replant his own seed, or whether he must purchase new seed stocks from the foundation seed grower. The information is also frequently called for by the prospective purchaser of certified seed.

Certified seed must pass a third inspection at the time it is being graded for shipment. If it is found to meet all standards, especially freedom from ring rot, it may be put up with blue State Certification tags which are evidence to the buyer that the potatoes represent the best fraction of the seed from the given crop. It is, of course, well recognized that the quality of certified seed will vary from year to year, depending in large part on the abundance and activity of aphids during the growing season. Notwithstanding, the "blue tag" has, over a period of nearly thirty years, represented the best available seed stocks.

Growers of certified Chippewa seed especially, and growers of some other varieties as well, have found it desirable in years when disease spreads excessively to make use of top killers to prevent the further spread of disease. This practice has been adapted to the certified seed grower's ends and is based, of course, on the foundation seed grower's experience with disease control. The certified seed grower usually delays the operation beyond the time of early harvest chosen by the foundation grower, in order to gain in yield. He can afford to do this because

his product is for producers of table stock, who of all growers are the least concerned with virus diseases, except for those who wish to produce Green Mountains.

The seed produced by certified seed growers is offered to producers of table stock over a wide area east of the Mississippi, and even, on occasion, at greater distances. In years of surplus, some of the certified seed goes into table stock channels. A recent development has been the regrading of certified seed to remove the larger tubers for special table stock packs. There are several advantages to this practice, for all groups concerned, including consumers.

The production of table stock is a much less exacting process than that of raising seed. In general, little attention is paid to field diseases, except late blight, and insects are controlled only to prevent direct feeding injury. Table-stock growers rely on seed producers for their seed and usually they can obtain seed of such quality that they do not need to concern themselves with anything except ordinary cultural practices.

The only real restriction on table stock production is that exerted by grade standards at shipping time. This is concerned chiefly with the size and condition of the tubers and expect for leafroll, expressed as net necrosis, few diseases other than the common rots and stem-end browning are of any concern to the table stock grower because they have been reduced to a minimum by the growers of certified seed.

ORGANISMS MENTIONED

Bacteria:

Blackleg: *Erwinia carotovora* (Jones) Holland

Ring rot: *Corynebacterium sepedonicum* (Spieck. & Kotth.) Skapt.

Fungi:

Scab: *Actinomyces scabies* (Thax.) Güssow

Attacking aphids:

1. *Empusa aphidis* Hoff.
2. *Empusa sphaerosperma* (Fres.) Thax.
3. *Entomophthora coronata* (Cost.)

Early blight: *Alternaria solani* (E. & M.) Jones and Grout

Late blight: *Phytophthora infestans* (Mont.) de Bary.

Rhizoctonia: *Pellicularia filamentosa* (Pat.) Rogers.

Wilt: *Verticillium albo-atrum* R. and Ber.

Insects:

Aphid lion: *Chrysopidae*

Attacking aphids:

1. *Aphidius* spp.
2. *Diaeretus rapae* (Curt.)
3. *Pachyneuron altiscuta* How.
4. *Praon simulans* (Prov.)

Blister beetles: *Epicauta* sp.

Buckthorn aphid: *Aphis abbreviata* Patch

Colorado potato beetle: *Leptinotarsa decemlineata* (Say)

Common stalk borer: *Papaipema nebris* (Guen.).

Flea beetle: *Epitrix cucumeris* (Harr.).

Foxglove aphid: *Myzus convolvuli* (Kltb.) = *pseudosolani* Theob.

Green peach aphid: *Myzus persicae* (Sulz.)

Ladybird beetles:

1. *Adalia bipunctata* L.
2. *Coccinella novemnotata* Hbst.

Leafhoppers: *Cicadellidae*

Lygus bug: *Lygus oblineatus* (Say)

Potato aphid: *Macrosiphum solanifolii* (Ashm.)

Syrphid flies:

1. *Mesogramma* sp.
2. *Metasyrphus wiedemanni* (Johnson)
3. *Syrphis* sp.

Wireworms:

1. *Agriotes mancus* (Say)
2. *Cryptohypnus abbreviatus* Say
3. *Ludius* Spp

Plants:

Bird cherry: *Prunus pensylvanica* L.

Chokecherry: *Prunus virginiana* L.

Dwarf buckthorn: *Rhamnus alnifolia* L'Her.

Hemp nettle: *Galeopsis tetrahit* L.

Jimson weed: *Datura stramonium* L.

Wild radish:	*Raphanus raphanistrum* L.
Wild rutabaga:	*Brassica campestris* L.
Plum:	*Prunus nigra* Ait.
Potato:	*Solanum tuberosum* L.
Rose:	*Rosa palustris* Marsh., *Rosa rugosa* L.
Smartweed:	*Polygonum lapathifolium* L.
Viruses:	
Leafroll:	*Corium solani* Holmes
Mosaics:	
"A"	*Marmor solani* Holmes
"X"	*Marmor dubium* var. *vulgare* Holmes
"Y"	*Marmor cucumeris* var. *upsilon* Holmes
Combinations:	
Mild	Virus "A" and virus "X"
Rugose	Virus "Y" and virus "X"
Spindle tuber:	*Acrogenus solani* var. *vulgaris* Holmes